Efficiency Comparison of Scroll vs. Reciprocating Technology in Different Climates

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Abstract

There have been many studies and papers written on the efficacy of the current SEER (Seasonal Energy Efficiency Ratio) methodology as a seasonal performance measure for different climates. Most of these analyses conclude that the current SEER method is not adequate as a predictor of "real" energy cost or peak demand on utilities across the country. Most of the work done in this regard focuses on the variation in climate, humidity, building load, accuracy of rating data, etc. on the real energy use vs. the SEER rating. So while the conclusion is generally accepted that the current SEER rating method does not well predict actual energy use or efficiency, it seems to be generally accepted that the method does allow for a simple comparison between various manufacturers and models of equipment. It is this later concept that this paper will address.

Background

The original SEER methodology was based on a bin analysis that calculated cooling load, capacity, and efficiency over a range of ambient temperatures. Temperature data accumulated as a function of time (bin data), was used to weight the cooling operating hours based on time spent at each operating condition. This calculation method was retained for variable capacity systems but was dropped for single speed units in favor of a more simplistic formula that was found to closely approximate the bin calculation at some hypothetical "mid-range" climate.

The purpose of this paper is not to review or analyze the calculation methodology and the reader can find more information in the applicable AHRI and ASHRAE standards. However, it is important for this analysis to understand that the climate is a major factor in the efficiency that can be expected from any particular system. A system rated at 13 SEER can in reality be running anywhere from 93% to 113% of its rated efficiency depending on what location in the country it is installed (*Henderson/Sachs, "The Efficacy of SEER as a Seasonal Performance Measure for Different Climates", Proceedings of the 15th Symposium on Improving Building Systems in Hot and Humid Climates, July 2006*). The data behind that statement is based on the standard test protocol at 80 ºF indoor temperature. If the analysis were run at the more realistic indoor temperature of 72 ºF, the reality would be even farther from the rating. For the system used in this analysis, using a reciprocating compressor, the standard simplified SEER calculation resulted in a SEER rating of 13.9. By running the same test at 72 ºF rather than 80 ºF indoor temperature the standard simplified SEER calculation yields a 12.0 SEER resulting in a SEER number 13.7% lower using real world indoor ambient conditions.

If the even more realistic Bin Calculation Methodology is used, the SEER rating for this same system would be 12.2 SEER using temperature bin data for Washington, DC or 10.6 SEER if temperature bin data for Phoenix, AZ were used.

It can be seen from this analysis and many other studies that the climate has a major effect on the real energy efficiency of an air conditioning system. The rating for this system is 13.9 based on the current test and calculation standards but if the more realistic indoor temperature set point and temperature bin method is used, the SEER number could be as low as 10.6 in Phoenix, a difference of almost 24%, for exactly the same system.

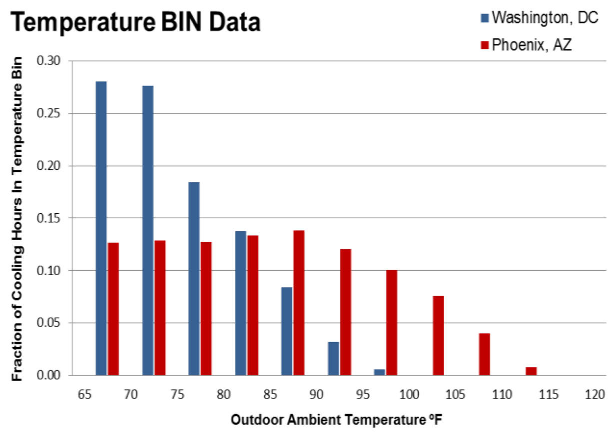

Figure 1

Compression Technology Effect

How about compression technology? We know from the compressor manufacturers published performance data that scroll compressors and reciprocating compressors display different performance as a function of temperature. As can be seen in Figure 2 below, at 50 ºF saturated evaporator temperature, the isentropic efficiency of the scroll compressor and reciprocating compressor are equal at around 105 ºF. However, as the ambient temperature varies from that point, the scroll efficiency drops off at a much greater rate than the reciprocating machine. Since the saturated temperature of the condenser typically runs around 15-20 º warmer than the ambient temperature, it would be expected that the SEER obtained by either the scroll or the reciprocating machine would be roughly equal at around 82 ºF which is exactly the basis for the standard simplified SEER calculation. However, as the ambient temperature increases, it would be expected that the reciprocating compressor would give higher system efficiency than the scroll.

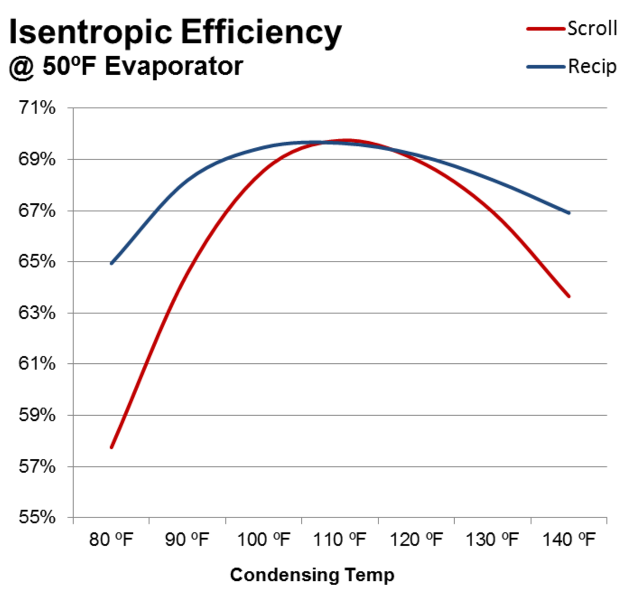

Figure 2

For purposes of this analysis the calculation methodology was modified slightly in an attempt to better characterize "real world" difference between the particular equipment used. The bin method uses the capacity of the system at 95 °F to establish a building load curve for a 10% oversized system. Since the capacity curves between the compression technologies are not identical, this method could not be realistically used because it would result in a different building load for the various equipment. So for this analysis the scroll compressor performance was used to establish the building load curve and this was held for the reciprocating machine as well. Also, the data at 72 ºF indoor ambient was used rather than the standard 80 ºF.

As can be seen in Figure 3, using the bin calculation method for Phoenix, AZ the calculation yields 10.3 SEER for the scroll and 10.6 SEER for the reciprocating compressor. Thus the bin method yields a 3% advantage for the reciprocating machine whereas the standard simplified method of calculating SEER has the two technologies much closer with only a 1.2% advantage for the reciprocating compressor in this analysis.

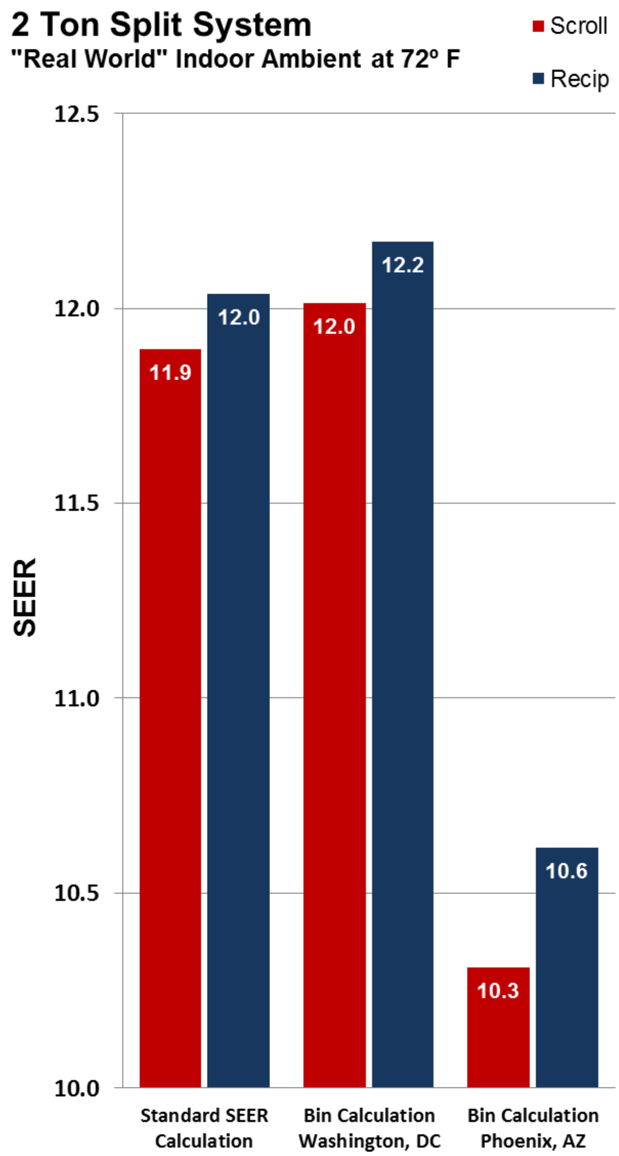

Figure 3

Conclusion

The current simplified method of calculating SEER based on a single operating temperature at 82 ºF is not an adequate predictor of "real world" energy usage nor is it a particularly sound method for comparing "real world" efficiency between compression technologies with different sensitivities to climate. The reciprocating compressor, being a variable compression ratio machine, has lower sensitivity to changes in climate than the scroll compressor which is a fixed compression ratio machine. The scroll compressor is optimized to operate most efficiently at around the 82 ºF point used in the standard SEER calculation but being more sensitive to differences in climate does not necessarily give optimum "real world" efficiency in warmer or cooler climates than the hypothetical "mid-range" climate on which the standard is based. The reciprocating compression technology in this analysis gives higher "real world" efficiency in warmer climates based on the bin calculation methodology. A more realistic approach to system rating methodology could enhance designer's efforts to pick the best technology for overall efficiency improvements across broad climate variances.